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(54) **EARPHONE ANTENNA, EARPHONE AND ELECTRONIC DEVICE EMPLOYING THE SAME**

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(30) **Foreign Application Priority Data**

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(51) **Int. Cl.**

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H01Q 1/44	(2006.01)
H01Q 9/30	(2006.01)
H01Q 21/28	(2006.01)
H01Q 21/30	(2006.01)
H04R 1/10	(2006.01)

(52) **U.S. Cl.**

CPC . ***H01Q 1/44*** (2013.01); ***H01Q 9/30*** (2013.01); ***H01Q 21/28*** (2013.01); ***H01Q 21/30*** (2013.01); ***H04R 1/1091*** (2013.01)

(58) **Field of Classification Search**

CPC H01Q 1/04
USPC 343/718, 790, 745, 876, 904
See application file for complete search history.

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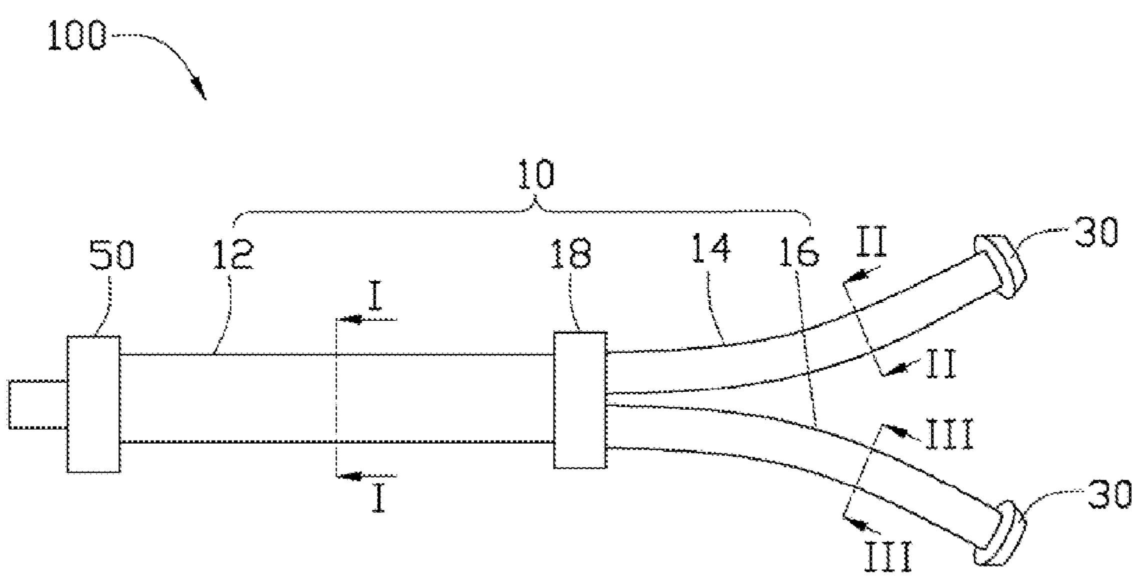
(57) **ABSTRACT**

One or more antennas within an earphone arrangement used in an electronic device includes a plurality of coaxial cables, a first antenna unit, a second antenna unit, and a third antenna unit. The coaxial cables carry radio frequency (RF) signals of different frequency bands. The first antenna unit, the second antenna unit, and the third antenna unit each include a radiating member. Each radiating member can receive and transmit RF signals of at least one frequency band, and the coaxial cables carry the RF signals to the device for processing.

20 Claims, 9 Drawing Sheets



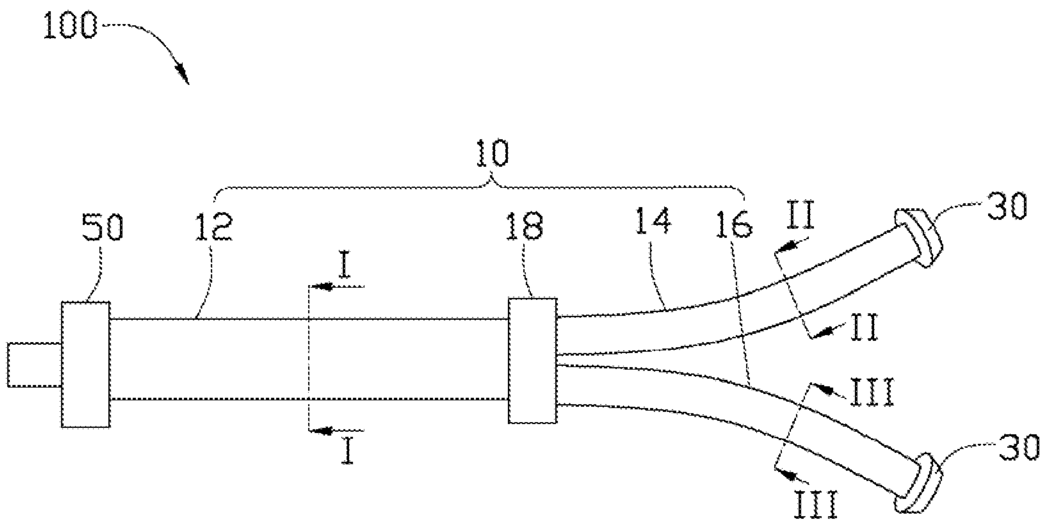


FIG. 1

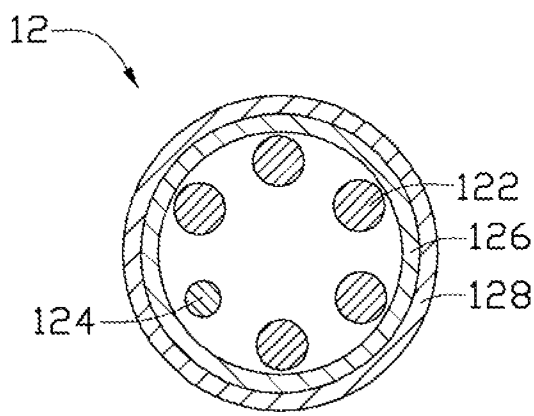


FIG. 2

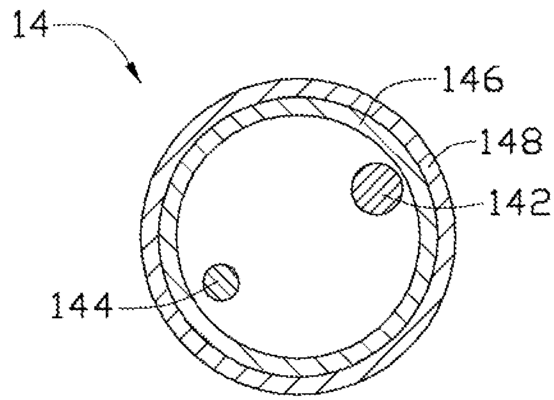


FIG. 3

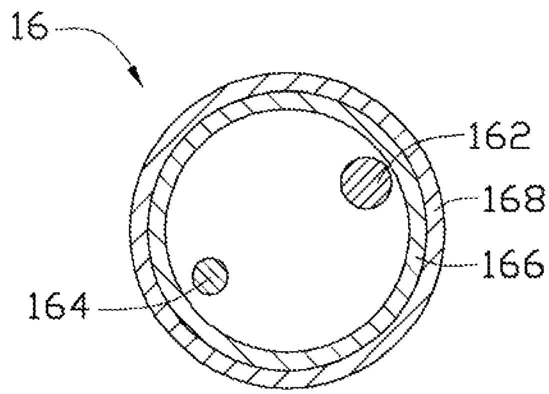


FIG. 4

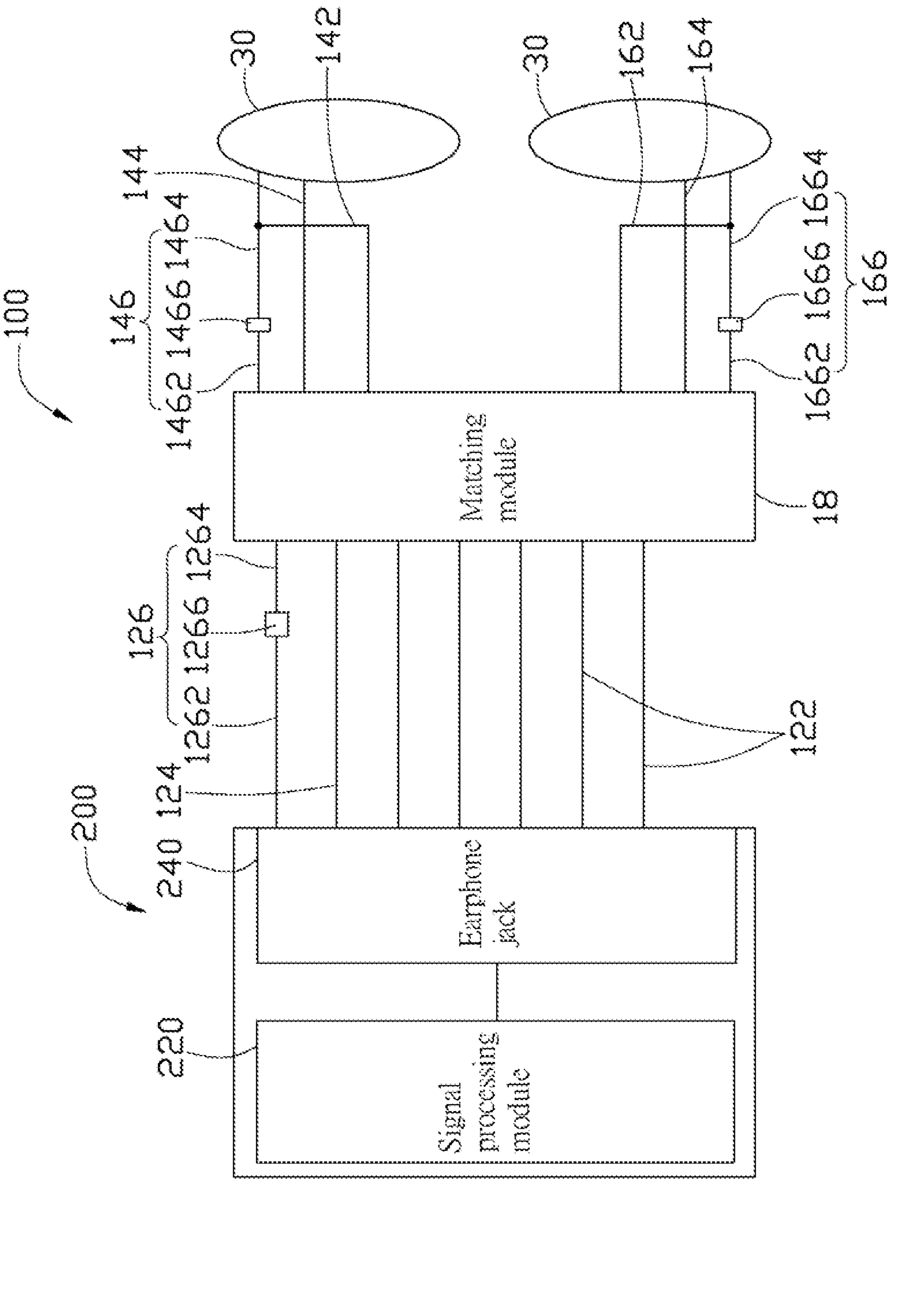

100
30
142
30
162
164
144
146
1464
1466
1462
1664
1666
1662
166
Matching module
18
126
1264
1266
1262
124
122
200
240
Earphone jack
220
Signal processing module

FIG. 5

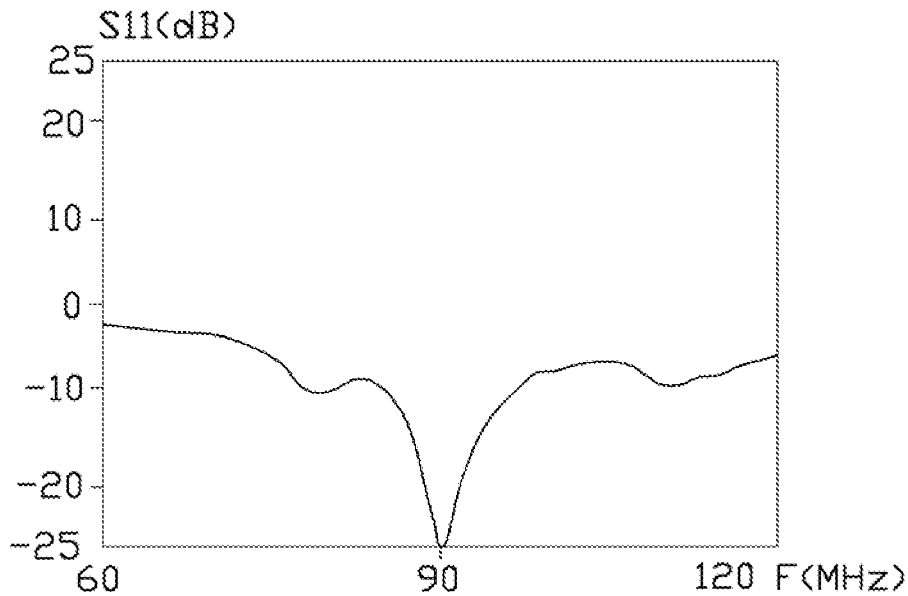


FIG. 6

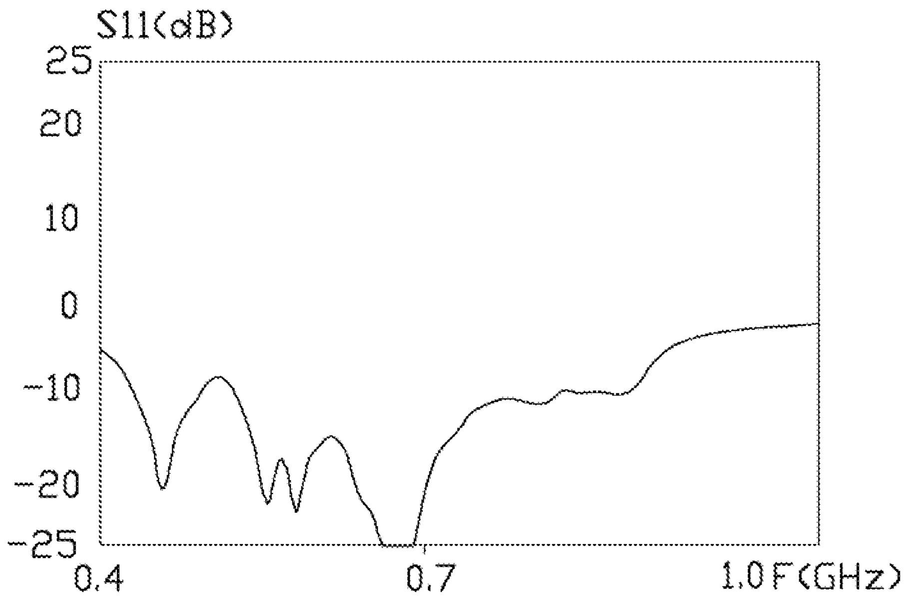


FIG. 7

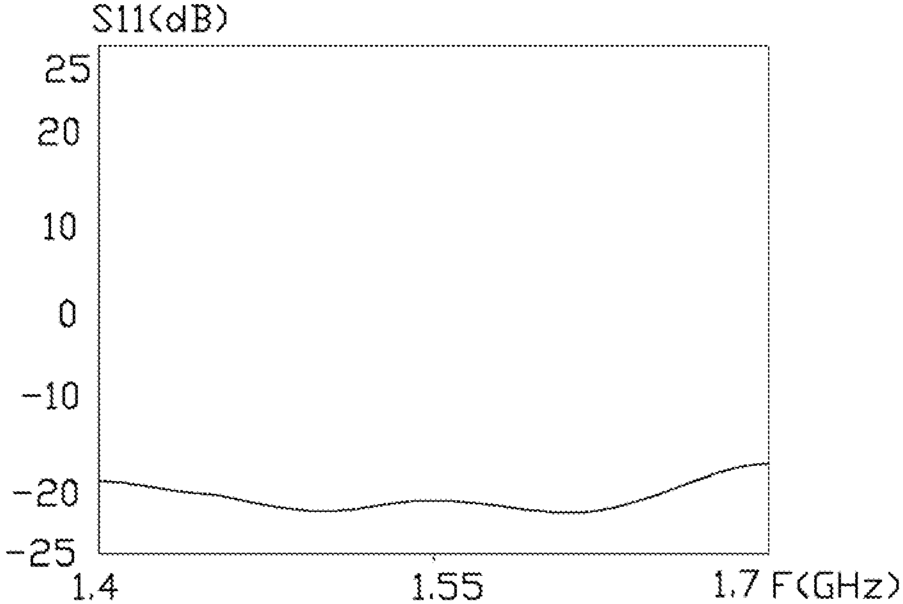


FIG. 8

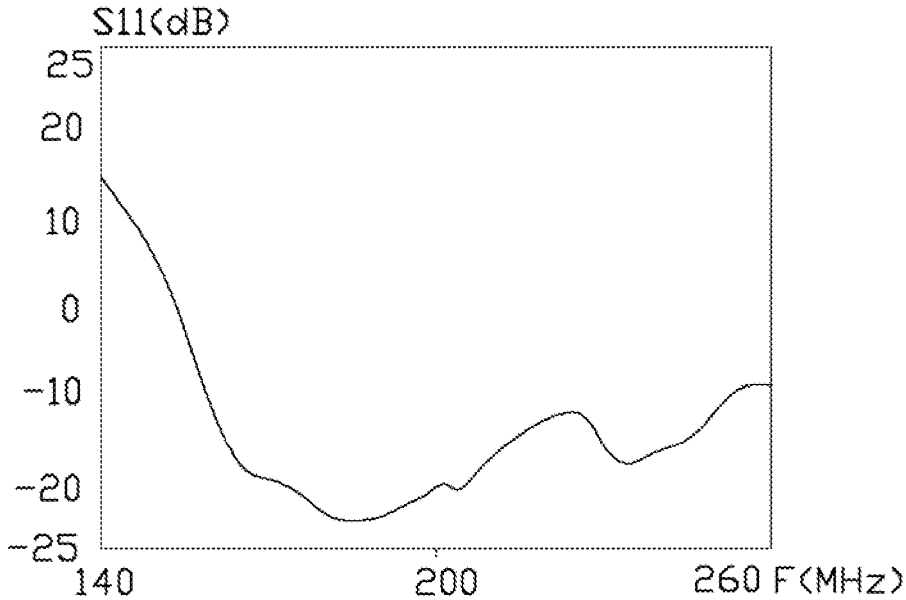


FIG. 9

EARPHONE ANTENNA, EARPHONE AND ELECTRONIC DEVICE EMPLOYING THE SAME

BACKGROUND

1. Technical Field

The disclosure generally relates to antennas, and more particularly to an earphone antenna, and an earphone and an electronic device employing the same.

2. Description of the Related Art

Electronic devices, such as mobile phones and frequency modulation (FM) radios, can receive FM wireless signals at 76 MHz-108 MHz through an earphone that is also implemented as a FM antenna to receive the FM wireless signals. However, such electronic devices are usually further designed to receive television (TV) signals such as very high frequency (VHF) signals or ultra high frequency (UHF) signals. Thus, an antenna which is capable of receiving TV signals is usually integrated in the electronic device, which can increase the size and weight of the electronic devices.

Therefore, there is room for improvement within the art.

BRIEF DESCRIPTION OF THE DRAWINGS

Many aspects of an earphone antenna, an earphone and an electronic device employing the same can be better understood with reference to the following drawings. The components in the drawings are not necessarily drawn to scale, the emphasis instead being placed upon clearly illustrating the principles of the earphone antenna, earphone and electronic device employing the same. Moreover, in the drawings, like reference numerals designate corresponding parts throughout the several views. Wherever possible, the same reference numbers are used throughout the drawings to refer to the same or like elements of an embodiment.

FIG. **1** is a schematic view of an earphone including an earphone antenna, according to an embodiment of the disclosure.

FIG. **2** is a cross-sectional view of the earphone antenna taken along line I-I of FIG. **1**.

FIG. **3** is a cross-sectional view of the earphone antenna taken along line II-II of FIG. **1**.

FIG. **4** is a cross-sectional view of the earphone antenna taken along line of FIG. **1**.

FIG. **5** is a block view of the earphone electrically connected to an electronic device of the disclosure.

FIG. **6** is a graph of a simulated test result when the earphone is receiving DVB-UHF radio frequency (RF) signals, disclosing an insertion loss varying with frequencies.

FIG. **7** is a graph of a simulated test result when the earphone is receiving FM RF signals, disclosing an insertion loss varying with frequencies.

FIG. **8** is a graph of a simulated test result when the earphone is receiving GSM and DAB-L-BAND RF signals, disclosing an insertion loss varying with frequencies.

FIG. **9** is a graph of a simulated test result when the earphone is receiving DVB-VHF and DAB-III RF signals, disclosing an insertion loss varying with frequencies.

DETAILED DESCRIPTION

FIG. **1** shows a schematic view of an earphone **100** including an earphone antenna **10**, according to an embodiment of the disclosure. The earphone **100** is electrically connected to an electronic device **200** (schematically shown in FIG. **5**) to listen to audio signals, and the electronic device **200** can be a mobile phone.

Referring to FIG. **5**, the earphone **100** further includes loudspeakers **30** and an earphone plug **50**. In this embodiment, the earphone antenna **10** is in the form of an earphone wire electrically connected between the loudspeakers **30** and the earphone plug **50**, and is capable of delivering audio signals and receiving wireless signals. The loudspeakers **30** are used as left-channel/right-channel speakers to output sound in response to an electrical audio signal input. The earphone plug **50** is electrically connected to a corresponding earphone jack of the electronic device **200** to receive audio signals from a signal source such as an audio amplifier or an audio microchip.

The electronic device **200** includes a signal processing module **220** and an earphone jack **240** electrically connected to the signal processing module **220**. The signal processing module **220** is capable of transforming and converting radio frequency (RF) signals from the earphone antenna **10** into corresponding audio signals.

The earphone jack **240** receives the processed audio signals from the signal processing module **220** and transmits the audio signals to the loudspeakers **30** through the earphone plug **50** and the earphone antenna **10**. The earphone jack **240** is further capable of receiving RF signals from the earphone plug **50** and transmitting the RF signals to the signal processing module **220**.

In this embodiment, the RF signal received by the earphone antenna **10** can be a frequency modulation (FM) signal whose RF range is about 88 MHz-108 MHz, a digital video broadcasting (DVB)-ultra high frequency (UHF) signal whose RF range is about 470 MHz-860 MHz, or a global positioning system (GPS) signal whose RF range is about 1570 MHz-1580 MHz. The RF signal can also be a DVB-very high frequency (VHF) signal whose RF range is about 170 MHz-240 MHz, or a digital audio broadcasting (DAB) signal whose RF range is about 1852 MHz-1892 MHz or 174 MHz-240 MHz.

The earphone antenna **10** includes a first antenna unit **12**, a second antenna unit **14**, a third antenna unit **16**, and a matching module **18**. The first antenna unit **12** is electrically connected between the earphone plug **50** and the matching module **18**, and the second antenna unit **14** and the third antenna unit **16** are electrically connected to the first antenna unit **12** through the matching module **18**.

Referring to FIG. **2**, the first antenna unit **12** includes a plurality of coaxial cables **122**, an audio cable **124**, a first radiating member **126**, and an insulating sheath **128**. The coaxial cables **122**, the audio cable **124** and the first radiating member **126** are electrically connected to the earphone jack **240** of the electronic device **200** through the earphone plug **50**.

In this embodiment, the number of the coaxial cables **122** is five, each of which is sized to have an effective length that allows for respectively receiving and carrying RF signals of the DVB-UHF band, the GPS band, the DVB-VHF band, the DAB-L band and the DAB-III band. The coaxial cables **122** are embedded in flexible insulating material and are insulated from each other to prevent mutual interference and to protect the signals against external electromagnetic interference. The audio cable **124** is separated from the coaxial cables **122** by the flexible insulating material, and is capable of carrying and delivering audio signals from the signal processing module **220** to the loudspeakers **30**.

The insulating material, the coaxial cables **122** and the audio cable **124** are shielded and surrounded by the first radiating member **126**. In this embodiment, the first radiating member **126** is made of a conductive material(s), such as copper or other metal to receive and transmit the RF signals. The first radiating member **126** includes a first radiating section **1262**, a second radiating section **1264**, and an isolation block **1266** connected between the first radiating section **1262** and the second radiating section **1264**.

In this embodiment, the first radiating section **1262** is electrically connected to the earphone jack **240** through the earphone plug **50**, and has an effective length that allows for the receiving and carrying of RF signals of the FM band and deliver those signals to the electronic device **200** through the earphone jack **240** and the earphone plug **50**. The second radiating section **1264** is electrically connected to the earphone jack **240** through the matching module **18** and one of the coaxial cables **122**, and the earphone plug **50**, and has an effective length that allows for the receiving of DVB-UHF band signals. The first radiating section **1262** and the second radiating section **1264** are separated by the isolation block **1266** to prevent interference with each other, by means of a substantial (e.g. 50 mm) gap.

The isolation block **1266** is made from Manganese (Mn), Zinc (Zn) or other metal(s), and is located at the gap to prevent interference between the first radiating section **1262** and the second radiating section **1264**. The insulating sheath **128** is made of plastic, and surrounds and shields the first radiating member **126** to protect the first radiating member **126**.

Referring to FIGS. **3** and **5**, the second antenna unit **14** includes a coaxial cable **142**, an audio cable **144**, a second radiating member **146**, and an insulating sheath **148**. The coaxial cable **142** is embedded in the flexible insulating core and has an effective length that allows for carrying and transmitting RF signals. The audio cable **144** is electrically connected between the matching module **18** and one of the loudspeakers **30** to carry and deliver audio signals to the loudspeaker **30**. The audio cable **144** is separated from the coaxial cable **142** by the flexible insulating material.

The insulating material, the coaxial cable **142** and the audio cable **144** are shielded and surrounded by the second radiating member **146**. In this embodiment, the second radiating member **146** is made of conductive material(s), such as copper or other metal to receive, transmit and carry RF signals. The second radiating member **146** includes a third radiating section **1462**, a fourth radiating section **1464**, and an isolation block **1466** connected between the third radiating section **1462** and the fourth radiating section **1464**.

In this embodiment, the third radiating section **1462** is electrically connected to the matching module **18** and has an effective length that allows for the receiving and carrying of GPS band signals. The fourth radiating section **1464** is electrically connected to one of the loudspeakers **30** and has an effective length that allows for the receiving and carrying of DVB-VHF band signals. The coaxial cable **142** is electrically connected between the matching module **18** and the fourth radiating section **1464**. The third radiating section **1462** and the fourth radiating section **1464** are separated by the isolation block **1466** which creates a substantial gap of about 50 mm to prevent interference between the third radiating section **1462** and the fourth radiating section **1464**.

The isolation block **1466** is made from Mn, Zn or other metal(s) and is located at the gap between the third radiating section **1462** and the fourth radiating section **1464**. The insulating sheath **148** is made of plastic, and surrounds and shields the first radiating member **146** to protect the first radiating member **146**.

Referring to FIGS. **4** and **5**, the third antenna unit **16** includes a coaxial cable **162**, an audio cable **164**, a third radiating member **166**, and an insulating sheath **148**. The coaxial cable **162** is embedded in the flexible insulating material and functions as a conductor of RF signals, and has an effective length that allows for carrying RF signals. The audio cable **164** is electrically connected between the matching module **18** and the other loudspeaker **30** to carry and deliver audio signals to the loudspeaker **30**. The audio cable **164** is separated from the coaxial cable **164** by the flexible insulating material.

The coaxial cable **162** and the audio cable **164** are surrounded and shielded by the third radiating member **166**. In this embodiment, the third radiating member **166** is made of conductive material(s), such as copper, to receive and transmit RF signals. The third radiating member **166** includes a fifth radiating section **1662**, a sixth radiating section **1664**, and an isolation block **1666** connected between the fifth radiating section **1662** and the sixth radiating section **1664**.

In this embodiment, the fifth radiating section **1662** is electrically connected to the matching module **18** and has an effective length that allows for the receiving and carrying of DAB-L band signals (e.g., 1852 MHz to 1892 MHz). The sixth radiating section **1664** is electrically connected to the other loudspeaker **30** and has an effective length that allows for the receiving and carrying of DAB-III band signals (e.g., 174 MHz to 240 MHz). The coaxial cable **162** is electrically connected between the matching module **18** and the sixth radiating section **1664**. The fifth radiating section **1662** and the sixth radiating section **1664** are separated by the isolation block **1666** to prevent mutual interference, and the isolation block **1666** creates a substantial 50 mm gap between the fifth radiating section **1662** and the sixth radiating section **1664**.

The isolation block **1666** is made from Mn, Zn or other metal(s), and is located at the gap between the third radiating section **1662** and the sixth radiating section **1664** to prevent interference between the fifth radiating section **1662** and the six radiating section **1664**. The insulating sheath **168** is made of plastic and is capable of surrounding and shielding the third radiating member **166** to protect the third radiating member **166**.

Referring to FIGS. **1** and **5**, the matching module **18** is electrically connected to the first antenna unit **12**, the second antenna unit **14** and the third antenna unit **16**, to provide impedance matching and to filter out the noise from wireless signals. The matching module **18** is integrated with a plurality of conventional matching circuits (not shown) electrically connected to the coaxial cable **122**, the audio cable **124** and the second radiating section **1264** of the first antenna unit **12**, the coaxial cable **142**, the audio cable **144** and the third radiating section **1462** of the second antenna unit **14**, the coaxial cable **162**, and the audio cable **164** and the fifth radiating section **1662** of the third antenna unit **16**. Thus, any of the different signals can be carried by the radiating sections **1264**, **1462**, **1464**, **1662** and **1664** to the electronic device **200** through the matching module **18** and the corresponding coaxial cable **122**. The audio signals from the electronic device **200** may be carried and delivered to the loudspeakers **30** through the audio cable **124**, the matching module **18**, and the audio cables **144** and **164**.

In use, the earphone **100** is electrically connected to, or is inserted into, the earphone jack **240** of the electronic device **200**, and thereby the first radiating section **1262** has an electrical connection(s) with signal processing module **220** through the earphone jack **240**. The second radiating section **1264**, the third radiating section **1462**, the fourth radiating section **1464**, the fifth radiating section **1662** and the sixth radiating section **1664** each have an electrical connection(s) with the signal processing module **220** through the matching module **18** and the corresponding coaxial cables **122**. Thus, the radiating sections **1262**, **1264**, **1462**, **1464**, **1662** and **1664** of the earphone antenna **10** can receive signals of the FM band, the DVB-UHF band, the GPS band, the DVB-VHF band and the DAB band, and carry and deliver those signals to the signal processing module **220** through different electrical paths. The signal processing module **220** then converts the signals into audio signals, and carries the audio signals to the loudspeakers **30** through the earphone jack **240**, the audio cables, and matching module **18**.

FIGS. **6-9** show simulated test graphs of the earphone antenna **10**, disclosing insertion loss which varies with frequency. The horizontal axis of each test graph is expressed as the frequency, and the vertical axis of each test graph is expressed as the value of the insertion loss. When the earphone antenna **10** is working in any of the FM, the DVB-UHF, the GPS, the DVB-VHF, or the DAB bands, the corresponding insertion loss of each operating band is less than −5 dB, which meets the design requirements of the earphone antenna **10**.

The band capabilities of the earphone antenna **10** are not limited to the six operating bands described, it can also deal with other frequency bands, such as WiFi and BLUETOOTH, which can be achieved by changing the physical dimensions such as the effective lengths of the radiating members. It is known to those skilled in the art that the effective length of an antenna radiating member is directly related to the frequency at which the antenna responds. In addition, any of the first antenna unit **12**, the second antenna unit **14** and the third antenna unit **16** can include more than two radiating members.

In summary, the coaxial cables are surrounded and shielded by radiating members, and each radiating member is divided into different radiating sections that function as antennas to receive RF signals of many different frequency bands, which can reduce the size and weight of the electronic device **200** itself. Moreover, the integrity of the signals received is maintained by the use of isolation blocks between the radiating sections, therefore, signals of different bands are protected from external interference.

In the present specification and claims the word "a" or "an" preceding an element does not exclude the presence of a plurality of such elements. Further, the word "comprising" does not exclude the presence of other elements or steps than those listed.

It is to be understood, however, that even though numerous characteristics and advantages of the disclosure have been set forth in the foregoing description, together with details of the structure and function of the disclosure, the disclosure is illustrative only, and changes may be made in detail, especially in the matters of shape, size, and arrangement of parts within the principles of the disclosure to the full extent indicated by the broad general meaning of the terms in which the appended claims are expressed.

What is claimed is:

1. An earphone antenna, comprising:

a plurality of coaxial cables for transferring radio frequency (RF) signals of different frequency bands;

a first antenna unit comprising a first radiating member, the first radiating member for receiving, carrying and transmitting the RF signals;

a second antenna unit in electrical connection with the first antenna unit, the second antenna unit comprising a second radiating member; and

a third antenna unit in electrical connection with the first antenna unit, the third antenna unit comprising a third radiating member, wherein any one of the first radiating member, the second radiating member and the third radiating member receives and transmits RF signal of different frequency bands, any one of the first radiating member, the second radiating member and the third radiating member surrounds at least one of the coaxial cables, and the coaxial cables transfer the RF signals from the corresponding first antenna unit, the second antenna unit and the third antenna unit;

wherein the first radiating member comprises a first radiating section, a second radiating section, and an isolation block, the first radiating section is separated from the second radiating section by a gap, and the isolation block is located at the gap to prevent interference between the first radiating section and the second radiating section.

2. The earphone antenna as claimed in claim **1**, wherein the first radiating section and the second radiating section have an effective length that allows for receiving the RF signals of different frequency bands.

3. The earphone antenna as claimed in claim **2**, wherein the second radiating member comprises a third radiating section, a fourth radiating section and an isolation block connected between the third radiating section and the fourth radiating section, the third radiating section and the fourth radiating section have an effective length that allows for receiving RF signals of different frequency bands, and the third radiating section and the fourth radiating section are separated by the isolation block and create a gap to prevent interference between the third radiating section and the fourth radiating section.

4. The earphone antenna as claimed in claim **3**, wherein the third radiating member comprises a fifth radiating section, a sixth radiating section and an isolation block connected between the fifth radiating section and the sixth radiating section, the fifth radiating section and the sixth radiating section have an effective length that allows for receiving RF signals of different frequency bands, and the fifth radiating section and the sixth radiating section are separated by the isolation block and create a gap to prevent interference between the fifth radiating section and the sixth radiating section.

5. The earphone antenna as claimed in claim **1**, wherein the isolation block is made of a metal.

6. The earphone antenna as claimed in claim **4**, wherein each of the first antenna unit, the second antenna unit and the third antenna unit comprises an audio cable, the audio cable is separated from the corresponding coaxial cable and has an effective length that allows for the receiving of receiving and carrying audio signals, and the coaxial cable and the audio cable are surrounded and shielded by the corresponding radiating member.

7. The earphone antenna as claimed in claim **4**, wherein the earphone antenna receives RF signals of frequency modulation band, digital video broadcasting (DVB)-ultra high frequency band, global positioning system band, DVB-very high frequency band, digital audio broadcasting (DAB)-L band and DAB-III band.

8. The earphone antenna as claimed in claim **1**, further comprising a matching module, wherein the first antenna unit is electrically connected to the second antenna unit and the third antenna unit through the matching module, and the matching module provides impedance matching and filters out noise from the RF signals.

9. An earphone, comprising:

an earphone antenna for receiving and transmitting radio frequency (RF) signals, the earphone antenna comprising:

a plurality of coaxial cables for providing transmission lines for RF signals; and

a plurality of radiating members electrically connected to the corresponding coaxial cables, wherein each radiating member receives and transmits the RF signals of at least one frequency band, and at least one of the coaxial cables is shielded and surrounded by any of the radiating members to carry and deliver the RF signals from the corresponding radiating member;

wherein each radiating member comprises two radiating sections and an isolation block electrically connected between the two radiating sections, and the radiating sections are separated by the isolation block and form a gap to prevent interference between the two radiating sections.

10. The earphone as claimed in claim **9**, wherein each radiating section has an effective length that allows for the receiving and carrying RF signals of different frequency bands.

11. The earphone as claimed in claim **10**, wherein the isolation block is made of metal, and is located at the gap between the radiating members to prevent interference between the two radiating sections of any of the radiating members.

12. The earphone as claimed in claim **10**, wherein the earphone antenna further comprises an audio cable and an insulating sheath, the audio cable is separated from the coaxial cables and has an effective length that allows for the receiving of receiving, carrying and delivering audio signals, the coaxial cables and the audio cable are shielded and surrounded by the corresponding radiating member, and the radiating member is shielded and surrounded by the corresponding insulating sheath to protect the radiating member from electromagnetic interference.

13. The earphone as claimed in claim **12**, further comprising two loudspeakers and an earphone plug, wherein the earphone antenna further comprises a matching module electrically connected to the coaxial cables, the audio cables and the radiating members to provide matching and filter out noise from the RF signals, and the earphone antenna is electrically connected between the loudspeakers and the earphone plug, the earphone plug electrically connects to an electronic device, the audio cables are electrically connected to the loudspeakers to carry and deliver the audio signals to the loudspeakers.

14. The earphone as claimed in claim **9**, wherein the earphone antenna receives RF signals of frequency modulation band, digital video broadcasting-ultra high frequency band, global position system band, DVB-very high frequency band, digital audio broadcasting (DAB)-L band and DAB-III band.

15. An electronic device, comprising:

an earphone for carrying and delivering audio signals, the earphone comprising an earphone antenna for receiving and transmitting radio frequency (RF) signals, the earphone antenna comprising:

a plurality of coaxial cables for providing transmission paths for RF signals; and

a plurality of radiating members in electrical connection with the corresponding coaxial cables, wherein each radiating member surrounds and shields at least one of the coaxial cables, any of the radiating members receives the RF signals of different frequency bands, and carries and transmits the RF signals through the corresponding coaxial cable;

wherein each radiating member comprises two radiating sections and an isolation block electrically connected between the two radiating sections, and the radiating sections are separated by the isolation block and form a gap to prevent interference between the two radiating sections.

16. The electronic device as claimed in claim **15**, wherein each radiating section has an effective length that allows for the receiving and carrying the RF signals of different frequency bands.

17. The electronic device as claimed in claim **16**, wherein the isolation block is made of metal, and is located at the gap between the radiating members to prevent interference between the two radiating sections of any of the radiating members.

18. The electronic device as claimed in claim **16**, wherein the earphone antenna further comprises an audio cable and an insulating sheath, the audio cable is separated from the coaxial cables and has an effective length that allows for the receiving of receiving and carrying audio signals, the coaxial cables and the audio cable are shielded and surrounded by the corresponding radiating member, and the radiating member is embedded in the corresponding insulating sheath to protect the radiating member from electromagnetic interference.

19. The electronic device as claimed in claim **18**, further a signal processing module for converting the RF signals from the earphone antenna into corresponding audio signals, wherein the earphone further comprises two loudspeakers, the earphone antenna further comprises a matching module electrically connected to the coaxial cables, the audio cables and the radiating members to provide matching and filter out noise from the RF signals, and the earphone antenna is electrically connected to the loudspeakers, the audio cables are electrically connected to the loudspeakers to carry and deliver the audio signals from the signal processing module to the loudspeakers.

20. The electronic device as claimed in claim **15**, wherein the earphone antenna receives RF signals of frequency modulation band, digital video broadcasting (DVB)-ultra high frequency band, global position system band, DVB-very high frequency band, digital audio broadcasting (DAB)-L band and DAB-III band.

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